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RESISTANCE OF *RHYZOPERTHA DOMINICA* (COLEOPTERA: BOSTRYCHIDAE) TO PHOSPHINE IN THE PHILIPPINES

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ABSTRACT

The study was conducted to assess phosphine (PH_3) resistance of the lesser grain borer, *Rhyzopertha dominica* (F.), in the Philippines and to determine both the PH_3 concentration and exposure time required to control the resistant strains.

Five field strains and one laboratory strain of *R. dominica* were tested using the FAO discriminating dose test for adult insects. Three of the field strains were collected from the National Food Authority (NFA) warehouses in selected sites where PH_3 is commonly used. The sites represented the three major islands in the Philippines, Metro Manila (in Luzon), Cebu City (in the Visayas) and General Santos City (in Mindanao). The other field strains were collected from private warehouses in South Cotabato and Rizal.

High levels of resistance (>400×) were observed in the field strains collected from the NFA warehouses in Cebu City, Metro Manila and General Santos City. In contrast, low levels of resistance were detected in the strain from a private warehouse in South Cotabato (1.13×) and in the laboratory strains (1.65×). The strain from Rizal was still susceptible to PH_3.

The Cebu City strain was found to be the most resistant. It was subjected to a series of concentrations in order to determine both the PH_3 concentration and the minimum exposure period required for effective control. A concentration of 0.89 mg/L for 7 d at 25 ± 2°C provided the desired control. Based on this result, a dosage rate of 2 g/m^3 for a minimum 7-d exposure at 25°C and above is recommended for use in industry.

INTRODUCTION

The lesser grain borer, *Rhyzopertha dominica* (F.), is both the most abundant insect in stored maize and paddy in the Philippines and the most difficult to control (Sayaboc *et al.*, 1990). This can be attributed to both its tolerance of high temperatures and its ability to survive in grains with low moisture content (m.c.). *R. dominica* is known to be resistant not only to organophosphorous compounds such as pirimiphos methyl and malathion (Sayaboc

and Acda, 1990) but also to PH_3 (PH_3) (Gibe *et al.*, 1995). PH_3-resistance in stored-product insects was first reported in the Philippines in the government owned National Food Authority (NFA) warehouses in Metro Manila and Cebu City in 1995 (Gibe *et al.*, 1995). In those warehouses a high level of resistance was detected in *R. dominica* strains. The development of resistance in these insects is attributed to continuously exposing them to repeated inadequate PH_3 treatments. Resistance at low levels was also present in *Sitophilus zeamais*. Other major pests, such as *S. oryzae* and *Tribolium castaneum*, were found to be susceptible to PH_3.

The development of high levels of resistance in *R. dominica* prompted us to test resistance in other locations (in both government and private warehouses) in order to further evaluate resistance levels and determine the PH_3 concentration and exposure period required to control adult insects of tolerant strains.

MATERIALS AND METHODS

Insect collection

Field strains of *R. dominica* were collected by sieving infested grains from the NFA and private warehouses. At NFA, collections were made in areas where fumigation is commonly practiced. These represent the three major islands in the country: Metro Manila (in Luzon), Cebu City (in the Visayas) and General Santos City (in Mindanao). In private warehouses, insects were obtained from South Cotabato and Rizal. The collected insects were reared in the laboratory using the methods of the Entomology Branch of the Queensland Department of Primary Industries (QDPI), Australia. In addition to those collected, fenitrothion-selected *R. dominica*, bred at the NAPHIRE laboratory for more than 10 years, was also used as a test insect.

Resistance test

The strains were tested using the FAO recommended method and concentration (Anon., 1975). PH_3 was generated from a commercial aluminum phosphide formulation and collected over acidified water.

Adult beetles (1–2 weeks old) were confined within glass rings on a filter paper base inside gastight dessicators. The required concentration of PH_3 was injected from a gas-tight syringe through a rubber septum in the dessicator lid. Insects were exposed to a range of four concentrations for 20 h at 25 ± 2°C. After exposure, insects were held in culture medium. Mortality was assessed after 14 d. Percent mortality were later subjected to probit analysis.

The strain with the highest level of resistance among the strains tested was subjected to further tests. In this case, the Cebu strain was the most resistant in the dosage range used. Toxicity tests on adult *R. dominica* aged 1–2 weeks were carried out at 25°C and 70% r.h. in dessicators, according to the FAO method (Anon., 1975). The insects were exposed for 20 h, 3 d and 7 d. Mortality assessments were carried out 14 d after each designated exposure period.

RESULTS AND DISCUSSION

High levels of resistance were detected in strains collected from Cebu City, Metro Manila and General Santos City; the strains from Rizal and South Cotabato provinces, collected in private warehouses, were found to be susceptible (Table 1). In this experiment, the Rizal strain was used as a reference strain.

Table 2 shows the different dosages of PH_3 that provided 100% kill of the highly resistant strains of *R. dominica*. The concentration at which survival was observed is also presented. The Cebu strain had the highest dosage requirement (12.04 mg/L to obtain a

TABLE 1
Response of adult *R. dominica* exposed to PH_3 for 20 h based on mortality assessed after 14 d

Strain	Slope (±SE)	LC_{50} (mg/L) (95% FL)	$LC_{99.9}$ (mg/L) (95% FL)	RF
Cebu City	3.61 (±0.5	2.43 (1.788–2.960)	17.452 (10.857–47.85)	514.81
Metro Manila	2.56 (±0.4)	1.14 (0.763–1.475)	18.458 (10.07–61.41)	544.48
General Santos City	2.15 (±0.3)	0.62 (0.393–0.811)	16.827 (9.997–41.796)	496.37
South Cotabato	5.19 (±0.5)	0.0097 (0.0088–0.011)	0.0384 (0.0314–0.0514)	1.13
Laboratory strain	6.00 (±0.7)	0.017 (0.015–0.019)	0.056 (0.0434–0.086)	1.65
Rizal (susceptible)	4.70 (±0.4)	0.0075 (0.0067–0.0082)	0.0339 (0.0276–0.045)	–

TABLE 2
Dosages allowing survival and giving control of adults of *R. dominica* at 20 h exposure with their corresponding mortality (%)

Strain	Dosage (mg/L)	
	With survival	Complete control
Cebu City	8.0 (92.79)	12.04 (100)
Metro Manila	4.0 (95.00)	8.0 (100)
General Santos City	4.0 (93.33)	8.0 (100)
Laboratory strain	0.03 (92.97)	>0.03
Rizal (susceptible)		0.03 (100)

100% kill) while the Metro Manila and General Santos City strains required 8.0 mg/L. The Cebu strain survived the same dosage with 92.79% mortality.

Mills (1986) recommend a concentration of >0.80 mg/L for a 7-d exposure at 25°C to control highly resistant adults of *R. dominica*. This would give a Ct product of >134.4 mg L/h, which can be considered marginal when compared with the recommended concentration of 150 mg L/h for 7 d at 25°C given by Winks *et al.* (1980). In this study, a concentration of 0.89 mg/L for a 7-d exposure provided the same control (Table 3). Tyler *et al.* (1983) stated that a Ct product of 150 mg L/h for a minimum of 3 d is adequate. This is theoretically acceptable; however, in practice, this may not be appropriate. The tolerance of the egg and pupal stages is considerably greater than that of the larval and adult stages, and it is advantageous to lengthen exposure periods to give time for tolerant stages to develop into less tolerant ones (Winks, 1987).

TABLE 3
Dosages allowing survival and giving control of adults of *R. dominica* (Cebu strain) expressed in % mortality

Exposure at 25°C	Ref. strain	Concentration (mg/L)			
	0.03	0.71	0.89	1.0	1.5
20 h	100	–	–	–	–
3 d	–	–	–	98.33	100
7 d	–	99.12	100	–	–

Winks *et al.* (1980) found a Ct product of 150 mg L/h for at least 7 d sufficient to control all resistant species of insects; Mills (1986), however, found this concentration marginal for the resistant *R. dominica*, which is also true of our results (Table 4). Winks expected a Ct product of 150 mg L/h to be achieved in a well sealed enclosure over 7 d at a dosage rate of 1.5 g/m^3. However, a slight increase in the dosage rate to 2.0 g/m^3 for 7-d exposure is actually required to attain effective control.

TABLE 4
Phosphine concentrations needed to control populations of resistant *R. dominica* at 25°C

Exposure period	Ct (mg L/h)	
	Present work	Mills (1986)
3 d	108	104.4
7 d	149.5	134.4

PH_3 fumigation continues to play a major role in controlling stored-product infestations. It can still achieve effective control provided that adequate gas concentrations can be maintained and that the exposure period is extended so that tolerant stages of the insect can develop into susceptible stages within the exposure period.

The National Food Authority (NFA) has been using PH_3 for the past 30 years and still relies on it. PH_3 is currently applied at 2–3 g/m^3 for a 3-d exposure period. Based on this experiment, no change need be made in the rate. However, the exposure period should be extended to a minimum of 7 d.

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